PERIODIC OR RHYTHMIC VARIATION OF THE INTENSITY OF SHORT WAVE RADIO SIGNALS

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ABSTRACT. The present communication contains the results of detailed study of periodic or rhythmic types of fading of radio signals which are generally observed during the sun rise and sun set hours. It has been shown by measurement of the angles of arrival of the downcoming waves that such periodic fading may occur due to interference caused by two waves reflected either from one or two different layers of the ionosphere containing required amount of electronic density, when one or both the layers have slow vertical movement, presumbly due to rapid change of electronic density during the transition periods of ionization of the layers. It has been further shown that the development of slow periodic fading occurs due to the approach of maximum usable frequencies between the transmitting and receiving stations, and on such occasions the interference is caused by magneto-ionic components of reflected waves as suggested by Appleton and Beynon. The interference phenomena have been verified by recording the periodic fading of short wave signals transmitted from Delhi on 16 to 41 metre bands at various hours of the day during different months.

INTRODUCTION

Fading observations on short-wave radio signals have been found to be very useful in exploring the conditions of the ionosphere suitable for establishing radio communication between two stations situated apart and also for studying the possibility of diversity reception with spaced aerials as suggested by Banerjee and Mukerjee (1946). According to the mode of formation of various patterns of fading, they have been divided into two main categories, *viz.* (1) random and (2) periodic or rhythmic types. The present communication is concerned with the study of the second type of fading and their application to practical radio communications. For the purpose of explaining the various types of fading, the ionospheric data—recorded by the All India Radio, Delhi, have been used and the angles of arrival of downcoming waves have been measured, the method of which has been described in subsequent section.

THEORETICAL CONSIDERATIONS

The rhythmic or periodic type of variation of received signal, which is fairly regular and occurs mostly during sunrise and sunset hours can be explained to be due to interference fringes caused by either single and double reflections from one layer or two single reflections from two different layers of the ionosphere containing the required amonnt of electronic density for the purpose, when one or both the layers are moving up or down very slowly. It should be mentioned, however, that in case the fading pattern is smooth and periodic, there will be, at a time, only two paths of received travelling waves from the ionosphere and the intensity of the waves—should be fairly constant. This has been corroborated by measurement of angles of arrival of the downcoming waves during the observations of fading of signals and by observing the intensity of only one of the rays in the absence of the other. It may be pointed out that such slow movements of the ionospheric layers are difficult to observe by the usual 'pulse method' of measuring the height of the ionospheric layers with cathode ray oscillograph. Calculations show that the rate of movement of the layers for such cases may be of the order of 5 km/hr. whereas, a fairly sensitive instrument for 'pulse method' would measure the height of a layer with an approximation of $\pm$ 10 km/hr. Incidentally, it may be noted that these fringes in fading records indicate the possibility of measuring fairly slow rate of change in height of the ionospheric layers.

The conditions of reflection for different types of fading stated above have been verified generally for 25 and 19 metre bands with vertically polarised waves. The periodic nature of fading, is more often observed either in the morning after ground sun rise, or in the afternoon when the concentrations of electrons in the layers are either increasing or decreasing. It is more pronounced in the afternoon, presumbly due to higher electronic concentrations of the layers, permitting double reflections. It may be nentioned that periodic fading has also been observed by Appleton and Beynon (1947), which they have explained to be due to the interference bands caused by magneto-ionic components of the reflected waves. Under such circumstances the frequency of transmission approaches the maximum usable frequencies between transmitting and receiving stations. The periodic patterns of fading under the above conditions have been observed by us. Typical records of periodic fading and discussions thereon have been given in the later section.

PRINCIPLE AND METHOD OF MEASURING THE ANGLE OF ARRIVAL OF DOWNCOMING WAVES

The principle of the method of measuring the angle of arrival of downcoming waves is based on the fact that the intensity of the received signal on a vertical aerial depends on the vertical component of the electric field associated with the downcoming wave and the intensity of the signal received on a frame aerial depends on the horizental component of the magnetic field of the wave. This method of measurement was adopted by Appleton and Barnett (1925) for measuring the angle of arrival of the downcoming waves for medium wave transmission, in the presence of ground wave when the signal was detected by a square-law detector. In the present method employed by us modification has been made for the linear detector used and the absence of ground wave as shown below.

Let E and H be the electric and magnetic vectors respectively, associated with the downcoming radio wave as shown in Fig. 1 and let ϕ be the angle of

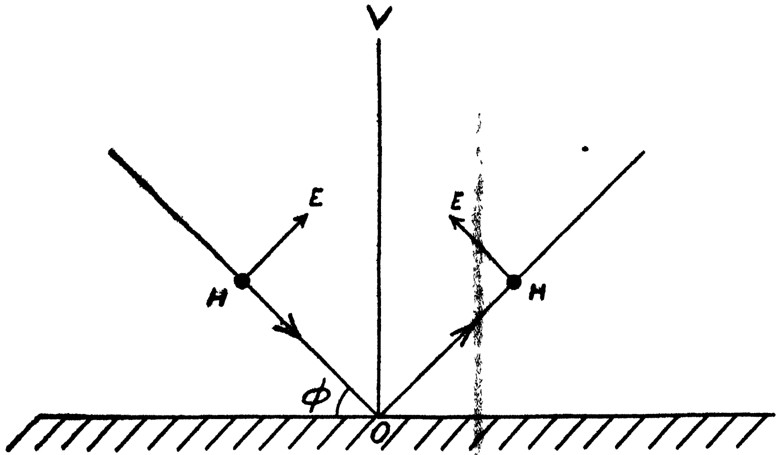

FIG. 1

arrival of the waves, *i.e.*, the angle subtended by the plane of propagation of the wave with the ground. It can be shown that the vertical aerial OV will be acted by an electric field $2E \cos\phi . \sin \omega t$, where ω is the pulsatance of the wave. A frame aerial directed towards the transmitter under the same conditions will be acted by a magnetic field $2H \sin \omega t$.

The instantaneous current flowing through a galvanometer in the second detector circuit of a superhet receiver connected with vertical aerial will therefore be given by $2\alpha K_v E \cos\phi \sin\omega t$, where α is constant of the detector characteristic and K_v is the constant of the vertical aerial.

The mean current i_v flowing through the galvanometer in the receiver with vertical aerial will, thus, be given by—

$$i_v = 2\alpha K_v E \cos\phi \qquad \dots (1)$$

Similarly, it can be shown that the mean current in the galvanometer with a frame serial will be given by—

$$i_f = 2\alpha K_f H \qquad \dots (2)$$

where suffix f indicates the corresponding values for frame aerial.

From equations (1) and (2) we get—

$$\frac{i_v}{i_f} = \frac{K_v E \cos\phi}{K_f H} \qquad \dots (3)$$

If the sensitivities of the two receivers are made equal by arranging the two aerials in such a manner that the vertical electric vector from a wave travelling along the ground, without any sky wave gives the same current in both the galvanometers, then, as $E \equiv H$, we have from equation (3),

$$\frac{i_v}{i_f} = \cos\phi \qquad \dots (4)$$

Thus from equation (4), knowing the deflections in the two galvanometers simultaneously, the angle of arrival of the downcoming wave can be determined.

One 5-valve superhet receiver was connected to a vertical aerial and another receiver of the same type was connected to a frame aerial. The sensitivities of the receivers were made equal with the help of a local oscillator kept fairly apart at the same horizontal level as the receiver. The noise level in the receivers was eliminated before starting the observations. The deflections in the sensitive mirror galvanometers were observed simultaneously when a signal was received and the angle of arrival of downcoming wave was calculated. Various fading patterns along with the angles of arrival of the downcoming waves are shown in the following section.

EXPERIMENTAL OBSERVATIONS AND DISCUSSIONS

Typical automatic and visual records of periodic fading on 25 and 19 metre bands from Delhi are shown in Figs 2 to 9. Visual records have been indicated in terms of galvanometer deflections in Figs. 5 and 6. During some of these observations angles of arrival of the downcoming waves were measured and the observed results have been explained by the existing electronic concentrations in the ionospheric layers at the hours of observations calculated from ionospheric data obtained from the Research Department, All India Radio, Delhi. For the sake of convenience, a brief summary of results of the above observations is given in Tables I and II. In order to check the results in the above tables, the electronic densities required for reflections of 25 and 19-metre bands for single and double reflections from E and F_2-layers between Delhi (lat. 28°, 35' N, long. 77°, 5'E) and Benares (lat. 25°.16 N. long. 83°.2E) situated at a distance of 678.4 km. over curved surface of the earth along with the angles of radiation, are given in Table III. The electronic densities have been calculated from the well-known relation,

$$\cos^2\beta = 1 - \frac{4\pi N e^2}{m\omega^2}$$

where β = angle of penetration of wave in the ionosphere.

N = electronic density.

e & m = charge and mass of electron respectively.

ω = pulsatance of the wave.

In view of the short wave lengths used in these observations, the collisional frequency of electrons with neutral atoms and molecules has been neglected, and for the sake of simplicity, the ionospheric layers have been assumed to be thin.

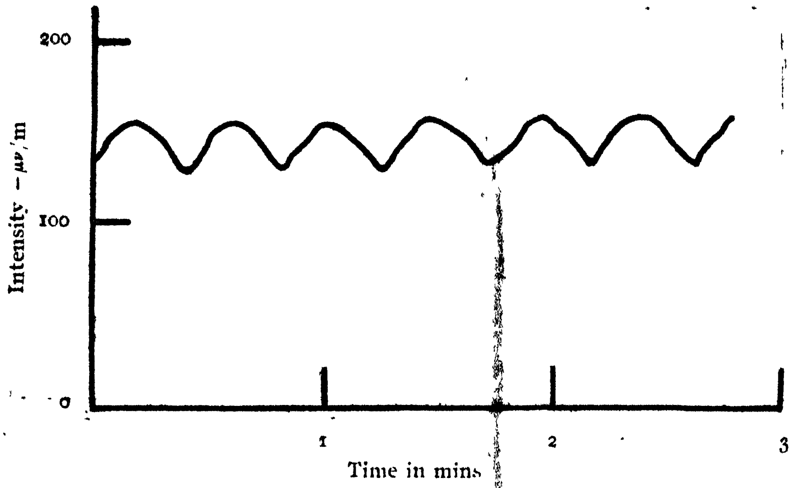

FIG. 2
19m—Delhi. 16 45 Hrs. I S.T , 22.12 46

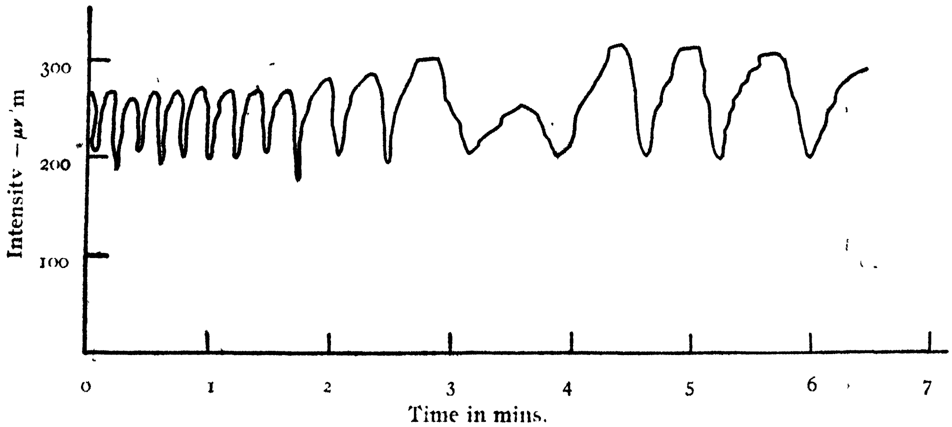

FIG. 3
25m. Delhi, 09.10 Hrs. I.S.T , 2.5 46

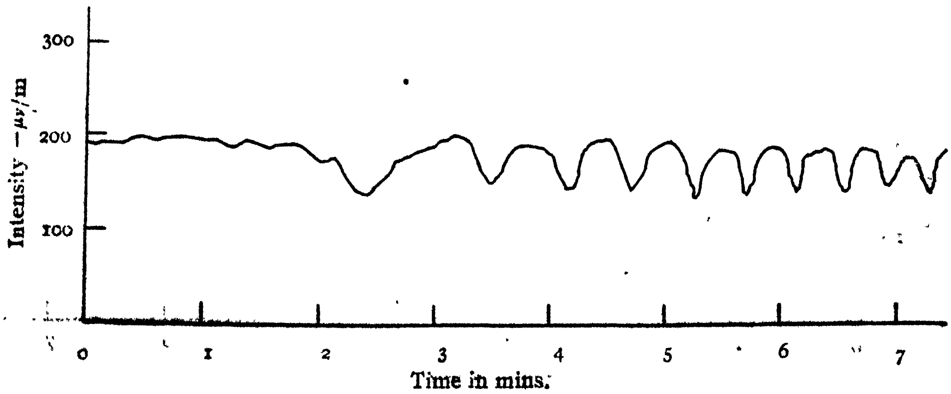

FIG. 4
19m—Delhi, 08.03 Hrs. I.S.T., 6.4.47

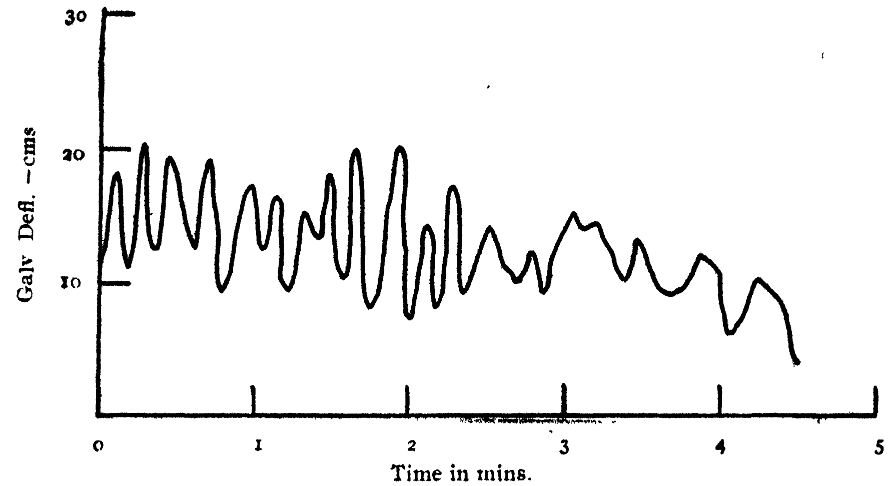

FIG. 5
19m – Delhi, 09.30 Hrs. I.S.T. 30.1.48

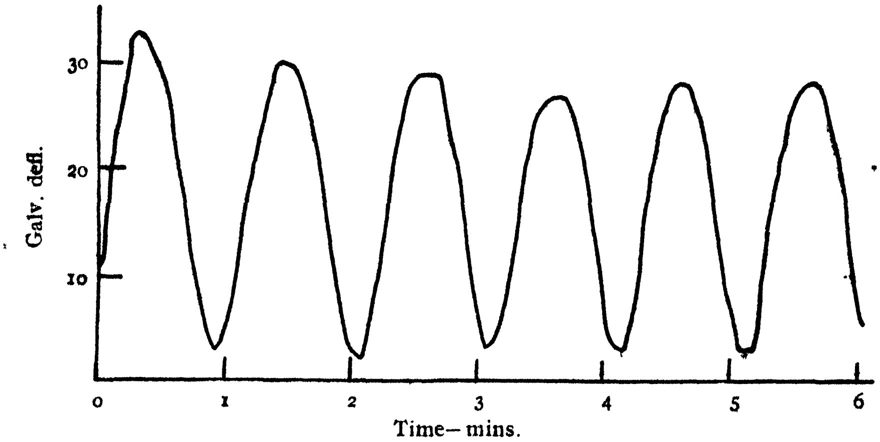

FIG. 6
19m – Delhi, 17.45 Hrs. I.S.T. 10.4.48

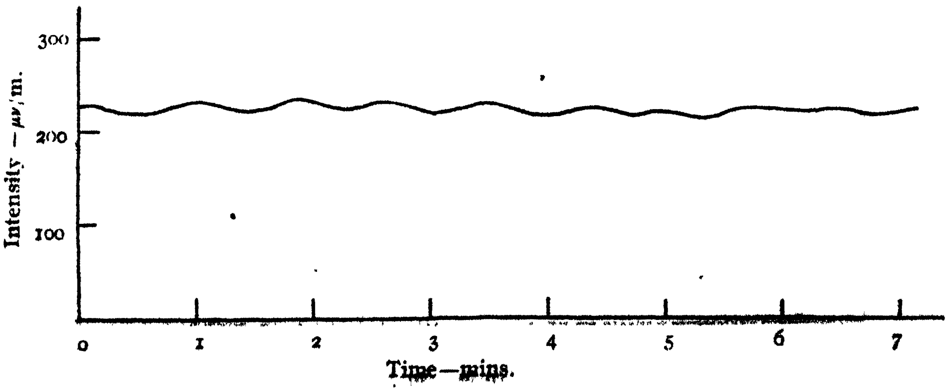

FIG. 7
19m—Delhi, 17.45 Hrs., 12.5.47

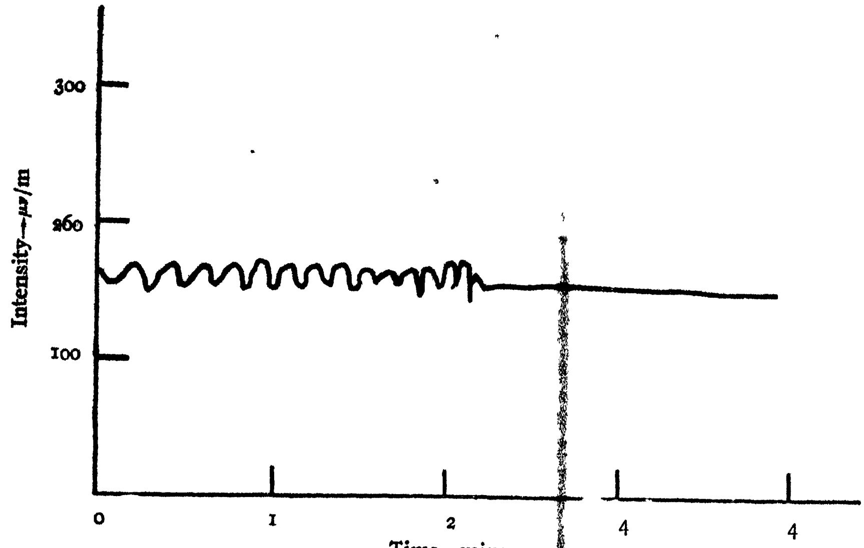

FIG. 8

19m—Delhi, 18.45 Hrs. I.S.T. 12.5 47

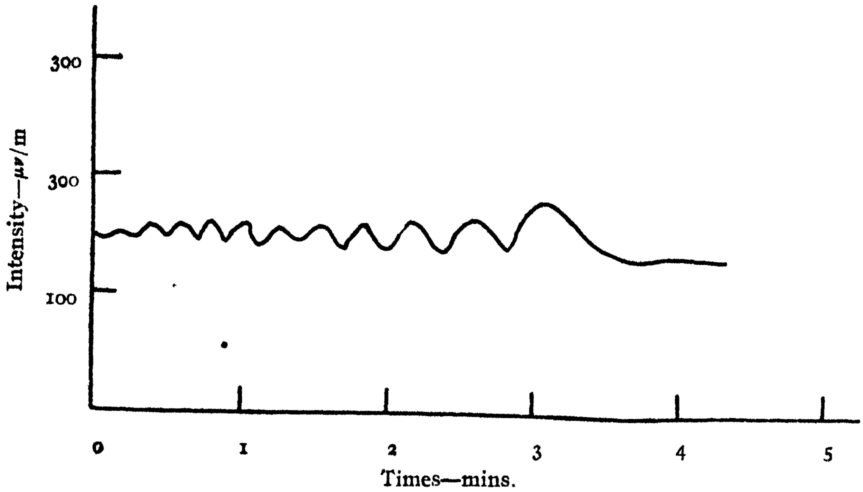

FIG. 9

19m—Delhi, 19.02 Hrs. I.S.T., 12.5.47

It will be observed from Table I that fading pattern under favourable circumstances develops into smooth periodic type as shown in Figs. 2 to 6. It will be seen from the table that this type of fading is obtained when there are only two reflections from either single layer or two different layers of the ionosphere with proper electronic concentration, when one or both the layers have slow vertical movement as described in the previous section.

Figs. 7 and 8 show the automatic records of fading observed on 12-5-47 for prolonged periodic variations of intensities of received signals on 19-metre band from Delhi. The periodic variations on this occasion persisted for more than one hour during which, however, the periods of variations changed. Simultaneous observations were recorded for the measurement of angles of arrival of the downcoming waves in order to find the layer from which the waves were being reflected. Fig. 9 shows a typical record of fading out of

TABLE I

Fig.	Date	Time in I.S.T	Wave band	Type of fading	Remarks
2	22-12-46	1645 hrs.	19-metre	Periodic	Single reflection from E (3.1×10^5 electrons/c.c, Single reflection from F_2 (1.5×10^6 electrons/cc.
3	2-5-46	0910 hrs.	25-metre.	Quasi-periodic and periodic.	Single or double reflection from F_2 (1.5×10^6 electrons/c.c).
4	6-4-47	0803 hrs.	19-metre	Random changing to periodic.	Single and double reflections from F_2-layer (2.3×10^6 electrons/c.c)
5	30-1-48	0930 hrs.	19-metre.	Periodic sometimes changing to random.	Single and double reflections from F_2-layer (2.1×10^6 etectrons/c.c).
6	10-4 48	1745 hrs.	19-metre	Smooth periodic with good intensity.	Single and double reflections from F_2-layer (4.5×10^6 electrons/c.c). Predicted value

TABLE II

Fig.	Date	Time in I.S T.	Wave band	Type of fading	Angles of Arrival of downcoming waves.	Remarks
7	12-5.47	1715 hrs.	19-metre.	Slow periodic	Around 46° or 60°	Single and double reflections from F_2-layer (2.0×10^6 electrons/c.c.) rate of movement of the layer—2.9 km/hr.
8	12-5-47	1845 hrs.	19-metre.	Quick periodic changing to nearly constant intensity.	Around 42°	Single reflection from F_2 (1.6×10^6 electrons/c.c).
9	12-5-47	1902 hrs.	19-metre.	Periodic. Fading out of signal due to reduction of electronic density.	Around 42°	Single reflection from F_2 (1.2×10^6 electrons/cc) Electronic concentration reduces to 1.0×10^6 electrons/c.c. after 1900 hrs.

TABLE III

Layer and height.	No. of reflections.	Angle of Radiation in degrees.	Required electronic densities for reflection in electrons/c c.	
			25-metre band	19-metre band
E– 100 km	1	13.7	1.359×10^5 to 1.470×10^5	2.297×10^5 to 2.547×10^5
	2	29.5	4.359×10^5 to 4.714×10^5	7.365×10^5 to 8.158×10^5
F_2– 360 km	1	44.5	8.937×10^5 to 9.665×10^5	1.510×10^6 to 1.673×10^5
	2	63.9	1.359×10^6 to 1.470×16^6	2.297×10^6 to 2.544×10^6

19-metre band signal obtained on the same day near about sun set, caused by reduction of electronic density.

Simultaneous measurements of the angles of arrival of downcoming waves at the time of observation indicated the presence of single and double reflections from F_2-layer as shown in Table II. Fig. 7 shows the periodic pattern obtained when there are single and double reflections from F_2-layer as indicated by the angle of arrival of the downcoming rays as shown in column 6 of Table II. These angles may be compared for single or double reflections from the ionospheric layers with the angles of radiation given in column 3 of Table III. It will be noted from the summary of observation for Fig. 7 that single and double reflections occurred from F_2-layer which might have moved up or down very slowly and the rate of movement of which has also been included in the table. As it has been mentioned previously, that such periodic fading patterns are more pronounced in the morning and afternoon hours, during the transition periods of ionization in the ionospheric layers which might cause slow variations of their equivalent heights.

Figs. 8 and 9 represent clear instance of interference bands produced by magneto-ionic components of reflected waves as suggested by Appleton and Beynon (1947). Observations in columns 6 and 7 of Table II will show that the electronic density at the time of observation was such that the frequency of transmission approached very near the maximum usable frequency between Delhi and Benares. Fig. 8 shows that the periodic patterns in the beginning of the record was due to interference between magneto-ionic components, and the period of which gradually decreased, and subsequently was superposed by interference caused by the Pedersen upper ray and the lower trajectory ray for ordinary component. After this, the ordinary component must have disappeared and then the intensity of the received signal became nearly constant, as the received signal was due to the extra-ordinary component only. Fig. 9 shows the resumption of periodicity in the received signal due to interference caused by upper and lower trajectory rays of the extra-ordinary component. The sequence of events described above may be attributed to the lowering of electronic density with time as shown in the last column of Table II and evidenced by the disappearance of signal shown in Fig. 9.

SUMMARY AND CONCLUSION

The periodic or rhythmic variations of intensity of short-wave radio signals which frequently occur during the sun rise and sun set hours, have been recorded for transmissions on 16-to 41-metre bands from Delhi. It has been shown by measuring the angles of arrival of downcoming waves during the time of observation of fading and using the ionspheric data recorded by the All India Radio, Delhi, that such periodic patterns may arise due to interference caused by two waves reflected either from one or two layers of the ionosphere having adequate amount of electronic density, when one or both the layers have slow vertical movement, presumably due to rapid change of concentration of electrons during the transition periods of ionization in the layers. It has been further observed that the periodic type of fading occurs when the electronic density in ionospheric layer is such that the frequency of transmission approaches the maximum usable frequency between the transmitting and receiving stations and the interference is then caused by magneto-ionic components of the radio wave, as shown by Appleton and Beynon.

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